Natural Disasters, Household Welfare, and Resilience: Evidence from Rural Vietnam

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NATURAL DISASTERS, HOUSEHOLD WELFARE AND RESILIENCE:EVIDENCE FROM RURAL VIETNAM

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Abstract

The study usescommune fixed-effect regressions to estimate the effect of natural disasters on household welfare and poverty, and subsequently examines household and community characteristics that can strengthen resilience of households to natural disasters. We find that all the three disaster types considered in this study including storms, floods and droughts have negative effects on household income and expenditure. Access to micro-credit, internal remittances and social allowances can help households strengthen the resilience to natural disasters. Households in communes with higher expenditure mean and more equal expenditure distribution are more resilient to natural disasters.

Keywords: Natural hazards, disasters, resilience, poverty, household welfare, Vietnam

JEL codes: O12, Q54, D12

1. Introduction

There is no doubt that the climate change has been the growing and biggest challenge to the people in the recent years. There is a rise in sea levels, the disappearance of ice, and changes in precipitation. A study by Dasgupta et al. (2009) on the potential impacts of sea level rise in 84 coastal developing countries shows that a one meter rise in sea level would affect about seven percent of agricultural land and 11 percent of the population, which could reduce the agriculture sector's GDP by 10 percent. According to IPCC(2007), "the average Northern Hemispheres temperatures during the second half of the 20th century were higher than during any other 50-year period in the last 500 years. It is possibly the highest in at least the past 1,300 years."

There is also an increase in the frequency and severity of natural disasters (IPCC, 2007; World Bank, 2010). Natural disasters cause physical and social-economic damages through direct, indirect, and secondary effects (Pelling et al., 2002; Benson, 1997; Lindell and Prater, 2003; Haen and Hemrich, 2006). The physical impacts of natural disasters include casualties and property damages. It is estimated that natural disasters caused 3.3 million deaths since 1970, or about 82,5 thousand a year (World Bank, 2010). Natural disasters also affect 255 million people annually (NarseyLal et al., 2009). World Bank (2010) estimates that the total damage caused by all hazards between 1970 and 2008 is around $2,300 billion (in 2008 dollars).Guha-Sapir et al. (2004) find that the economic cost related to natural disaster has increased 14-fold since the 1950s.

The impacts of natural disasters differ for different nations, regions, communities and individuals due to the differences in their exposures and vulnerabilities to natural disasters (Clark, *et al.*1998). There is aconsensus that the disasters cause more human losses in developing countries than the developed ones (Ludwig et al., 2007; Haen and Hemrich, 2006), and the poor are likely to suffer most from natural disasters (Ludwig et al., 2007; Haen and Hemrich, 2006; Kaplan, 2010). Although more than 60% of total damages caused by disasters occurred in high-income countries, the estimated damages as a share of

GDP are significantly greater in less developed and small countries (Okuyama and Sahin, 2009). Studies of Guha-Sapir (2011),Gaiha et al. (2010), Ludwig et al. (2007),Toya and Skidmore (2005), Sawada (2006)also findthat while the level of damages due to natural disasters is much higher in developed countries, the impact of disasters tends to be higher in less developed countries. In a country, poor households are more vulnerable to natural shocks in both response and recovery phases (Peacock et al., 1997; Fothergill and Peek, 2004; Wisner, *et al.* 2004).

The impact of natural disasters on households depends on the level of resilience of households and communities to the natural disasters. Exposed to the same disasters, households with better coping capacity and resilience can suffer less damage than those with low coping capacity and resilience. Basically,resilience is defined as capacity of households to absorb andmitigate damage or loss caused by natural disasters(Holling, 1973; Perrings, 2001).The resilience refers to the ability to recover from disasters and the ability to withstand disasters (Rose, 2004; Cannon, 2008; Briguglio et al.,2009). The resilience is also related to the coping capacity of households to the natural hazards (Greiving, 2006; Greiving et al., 2006). According to Rose (2004), resilience can take place at the three levels: micro level such as households and individual firms, medium level such as sectors and groups, and macro level with all individual units. The economic resilience depends on a large number of factors including macro and micro economic stability, social development and good governance (Briguglio et al. 2009). Assets, livelihood strategy, public transfers, and credit are important sources for households to increase resilience to shocks (Bruneau et al., 2003; Davies, 2013).

This study has the three main objectives. The first objective is to measure the effect of natural disasters on household welfare and poverty in rural Vietnam. As known, the impact of natural disasters depends on the resilience of households to natural disasters. An important question is which factors can increase the resilience of households to natural disasters. Thus, the second objective of this study is to examine whether a number of household and commune characteristics can strengthen the resilience of households to natural disasters in Vietnam. The third objective is to estimate the geographically heterogeneous effect of natural disasters. We will propose a simple method to construct spatial maps of the economic impact of natural disasters on households.

The study will focus on the economic effect of natural disasters on households in Vietnam for several reasons. Firstly, located in the South East Asia, Vietnam is considered as one of the most affected countries in the world by climate change. According to World Bank (2009), Vietnam is one of the 12 countries which are most vulnerable to climate change. UNISDR (2009) ranks Vietnam fourth in the global in terms of the absolute number of people exposed to floods, tenth to high winds from tropical cyclones, and sixteenth to droughts.Secondly, natural disasters occur throughout the country without very large events enable results applicable to average disasters (Noy and Vu, 2010). Thirdly, there are large surveys on households in Vietnam, which allows for the analysis of household welfare, resilience and natural disasters. More specifically, we will use the Vietnam Household Living Standard Surveys in 2004, 2006, 2008, and 2010 in this study.

Findings from the studies can provide useful information for policy makers on the adverse effects of natural disasters on household welfare and poverty in rural Vietnam. If natural disasters result in large economic damages for households, the government should have stronger and more effective policies and programs to reduce the adverse effects of natural disasters in Vietnam. Findings from the household and community characteristics associated with the resilience of households to natural disasters can be useful inputs for policies to strengthen the resilience to natural disasters.

The study is expected to have several contributions to the literature of environmental economics as well as development economics. Firstly, it provides empirical findings on the effect of natural disasters on household welfare and povertyand the factors that can mitigate the adverse effect of natural disasters in Vietnam - a developing country highly exposed to natural disaster.Secondly,it proposes a simple estimation method to estimate the geographically heterogeneous effect of natural disasters on household welfare.

The paper is structured into six sections. The second section provides a brief review of literature on the effect of natural disasters in the world and in the case of Vietnam. The third section presents the data set and descriptive analysis of welfare and natural exposure of households in rural Vietnam. The fourth and fifth sections present the estimation methods and empirical results on the effect of natural disasters, respectively. Finally, the sixth section concludes.

2. Literature review

Although there are numerous studies and documents on natural disasters, there are fewer empirical studies on the effect of natural disasters on household welfare. Baez and Santos (2008) estimate the impact of the two strong earthquakes in El Salvador on rural household income and poverty using panel data from Basis El Salvador Rural Household Surveys in 1996 and 2002. They find thatthe earthquakes reduced the household income by one-third. Masozera et al. (2007) find the Hurricane Katrina causes severe damages to households in New Orleans and its neighborhoods, regardless of their income, advancement and other social factors. Kurosaki (2010) investigates vulnerability of household consumption to natural disasters (floods, droughts, and pest attacks) in rural Pakistan, using two-period panel data surveyed in 2001 and 2004. His results show that depending on the nature of disasters and the characteristics of households, the sensitivity of consumption changes to village-level shocks differs across regions. He also concludes that land is effective in alleviating the ill-effects from disasters of different types.Recently, Rodriguez-Oreggia et al. (2012) find the adverse effect of natural disasters, especially flood and droughts, on human development and poverty in Mexico.

The literature of resilience to natural disasters tends to focus on cross-countries study and macro-economic level (Rose, 2004; Canon, 2008; Briguglio et al., 2009). Because of the difference in the resilience and coping capacity, the effects of disasters are differential at the country as well as at household levels (Kaplan, 2010; Cochrane, 1975; Benson, 1997; Noy, 2009). Briguglio et al. (2009) and Davies (2013) discuss several determinants of resilience at the micro and macro levels. At the household level, assets, livelihood strategy, public transfers, and credit are important factors to strengthen resilience to shocks (Bruneau et al., 2003; Davies, 2013). Ex ante risk management and ex post risk-coping behaviors and self-insurance mechanisms against large-scale disasters have been discussed in Sawada (2006).

There are several studies on the effect of natural disasters on households in Vietnam. Minot et al. (2006),Imai and Gaiha (2007), Thomaset al. (2010) find that income and expenditure of households in areas highly exposed to natural disasters are much lower

than the averageincome and expenditure.Thomaset al. (2010) estimatethat riverine floods and hurricanes cause household consumption losses of 23 and 52 percent, respectively. Recently, Wainwright and Newman (2011) look atcoping strategies of rural household toadverse income shocks. They find that liquid assets, public and private transfers can help households lessen the consumption fluctuation caused by natural shocks.

Our paper differentiates to the previous studies on natural disasters' impacts in Vietnam in three facets. Firstly, our papermeasures the effect of the three most frequent disasters in Vietnam including storms, floods and droughts using the most recent Vietnam Household Living Standard Surveys in 2004, 2006, 2008 and 2008. Secondly, we examine the role of a large number of household and commune characteristics in strengthening the resilience of households to disasters. Thirdly, we propose a simple method to estimate the geographically heterogeneous effect of natural disasters on household consumption.

3. Data and descriptive analysis

3.1. Data sets

This study relies on Vietnam Household Living Standard Surveys (VHLSS) in 2004, 2006, 2008 and 2010.[1]The VHLSSs were conducted by the General Statistics Office of Vietnam (GSO) with technical assistances from the World Bank. The surveys contain household and commune data. Data on households include basic demography, employment and labor force participation, education, health, income, expenditure, housing, fixed assets and durable goods, participation of households in poverty alleviation programs.[2]

Commune data include demography and general situation of communes, general economic conditions, non-farm employment, agriculture production, local infrastructure and transportation, education, health, and social affairs. The commune data contain

[1] There is the 2002 VHLSS. However, this survey does not contain data on natural disasters. As a result, we do not use this survey in our study.

[2] For more detailed discussion on the survey design and questionnaires of VHLSSs, see Phung and Nguyen (2008).

information on natural disasters happening in communes in previous years. Commune data can be merged with household data. Each of the VHLSSs covers more than ninethousand households. The data are representative for urban/rural and eight geographic regions. In this data, we use the rural samples, since data on urban disaster are not available in the surveys. The 2004, 2006, 2008 and 2010 VHLSSs covered6938, 6882, 6837, and 6750 rural households, respectively.

Data on disasters are collected from the rural commune questionnaires. Commune leaders are asked about different disasters that happened most recently during the past three years. There is no information on the number of disasters during the past three years. Thus, in this study we define the disaster variables as dummy variables indicating whether a disaster (storm, flood or drought) happened in a commune during the past two years. We define the disaster variables that happed during the past two years for the purpose of regression analysis, since our VHLSSs have a two year gap.

3.2. Descriptive analysis

Vietnam has been successful in poverty reduction. During the period 2004-2010, the proportion of rural population with per capita expenditure below the poverty line decreased from 25% to 17.9%.[3]However, the speed of poverty reduction is slow in the recent years. There is a large difference in the poverty rate between regions. West Northern Mountain is the poorest region, while South East and Red River Delta are the richest regions. Poverty is very high in ethnic minorities as well as households living in high mountains.

Table 1: Rural poverty rate by geographic areas and ethnicity during the period 2004-2010 (in percent)

	2004	2006	2008	2010
Regions				
Red River Delta	15.0	11.0	10.4	6.9
	(1.0)	(0.9)	(0.9)	(0.8)
East Northern Mountain	34.8	29.9	29.3	31.7

[3] In this study, we use the expenditure poverty line. This expenditure poverty line is equivalent to expenditure for consumption of 2,100 kcal/day plus some necessary non-food consumption.

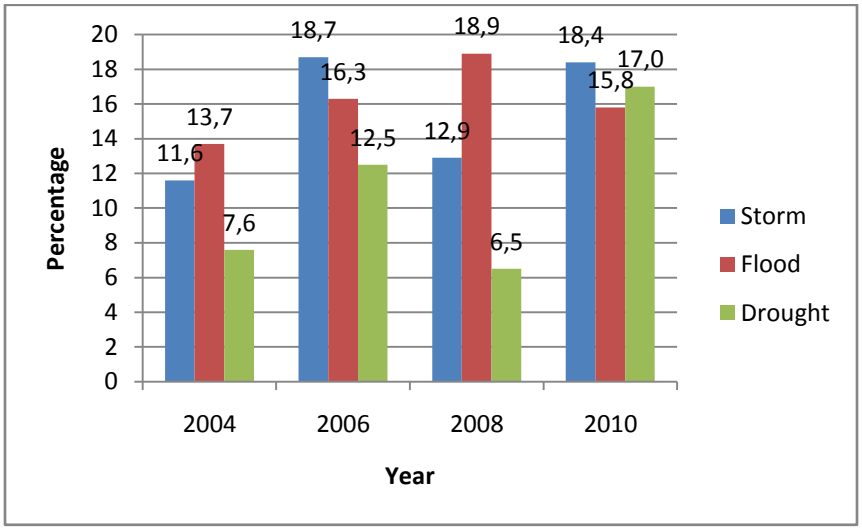
	2004	2006	2008	2010
	(1.6)	(1.6)	(1.6)	(1.6)
West Northern Mountain	65.5	56.4	52.0	50.7
	(2.8)	(3.0)	(3.2)	(3.0)
North Central Coast	36.4	33.1	25.9	21.0
	(1.9)	(1.9)	(1.9)	(1.7)
South Central Coast	25.0	17.1	18.2	18.1
	(2.0)	(1.8)	(1.9)	(1.8)
Central Highlands	41.4	34.4	31.4	28.8
	(2.8)	(2.7)	(2.7)	(2.5)
South East	10.9	9.9	5.7	10.4
	(1.4)	(1.4)	(1.0)	(1.4)
Mekong Delta	18.1	11.8	13.6	13.9
	(1.1)	(0.9)	(1.0)	(1.0)
Geographic types				
Coastal	22.4	18.3	13.6	10.0
	(2.2)	(2.1)	(1.8)	(1.7)
Delta	16.8	12.1	11.9	10.7
	(0.7)	(0.6)	(0.7)	(0.6)
Midlands/hill	18.8	14.8	10.1	6.6
	(2.2)	(1.9)	(1.6)	(1.4)
Low mountains	31.3	26.2	20.6	18.3
	(1.7)	(1.5)	(1.4)	(1.3)
High mountains	53.3	48.8	49.5	45.9
	(1.7)	(1.8)	(1.8)	(1.6)
Ethnic minorities				
Kinh/Hoa	17.9	13.5	11.7	9.7
	(0.6)	(0.5)	(0.5)	(0.5)
Ethnic minorities	62.7	54.0	52.5	52.7
	(1.5)	(1.6)	(1.6)	(1.5)
All rural Vietnam	25.0	20.4	18.7	17.9
	(0.6)	(0.6)	(0.6)	(0.5)

Note: Standard errors are in parentheses.
Source: Authors' estimation from the VHLSSs 2004, 2006, 2008 and 2010.

The four popular natural disasters are earthquakes, storms, floods and droughts (World Bank, 2010). In the world, droughts are the deadliest of the four hazard categories(World Bank, 2010). However, earthquakes rarely happens in Vietnam, while storms, floods and droughts take place more frequently and they are typical threats for a large part of Vietnam's agricultural areas.

In this section, we use the data from the VHLSSs to examine the pattern of disasters and household poverty in Vietnam. Figure 1 presents the proportion of rural population living in communes in which different disasters happened during the past two years. The proportion of people affected by disasters was higher in 2010 than in 2004. However, there was no clear trend in the disasters during the period 2004-2010. In 2010, the proportion of rural people living in communes with at least a storm happening during the past two years was 18.4%. The proportion of people in communes with floods and drought was smaller, at around 15.8% and 17.0%, respectively.

Figure 1: The percentage of population living in communes affected disasters



Source: Authors' estimations from the VHLSSs.

Vietnam is a country with highly diverse geographic and geomorphologic conditions. Drought is often recorded in the Central Highlands, while floods, typhoons and storms are very frequent in the Central Coast (Chaudry and Ruysschaert, 2007). Table 2 shows a spatial difference in disasters in Vietnam. Households in Central Coast are more likely to be affected by disasters, while those in Red River Delta are less likely to be affected by disasters. The proportion of households affected by stormsas well as floods is highest in Central Highland and Central Coast. In the West Northern Mountain, there canbe flash floods which can cause severe damages to people.

Vietnam has 54 ethnic groups, of which Kinh (Vietnamese) people account for around 85% of the total population.[4] Table 3 shows that ethnic minorities are more likely to live in communes with more frequent disasters than Kinh and Hoa. This is because ethnic minorities tend to stay in Northern Mountain, Central Highlands and Central Coast which are more exposed to disasters than other regions. The gap is highest for droughts: 26.1% of ethnic minorities and 14.9% of Kinh/Hoa live in communes with droughts happening the past two years, respectively.

Table 3 also presents the proportion of households living in communes with disasters by expenditure quintiles. There is quite clear correlation between poverty rate and disasters. Poor households tend to live in communes with high probabilities of disasters. In 2010, the proportion of people in the lowest expenditure quintile faced storms, floods, and droughts during the past two years is 23.5%, 20.1%, and 22.5%, respectively. The corresponding figures for people in the highest expenditure quintile are 13.7%, 9.6%, and 10.8%.

[4]Hoa (Chinese) mainly lives in cities and have higher income than other ethnic minorities. Thus Hoa is grouped with Kinh (Vietnamese) in this study.

Table 2: The percentage of population living in communes affected disasters by geography

	The percentage of population living in communes affected by storms				The percentage of population living in communes affected by floods				The percentage of population living in communes affected by droughts			
	2004	2006	2008	2010	2004	2006	2008	2010	2004	2006	2008	2010
Regions												
Red River Delta	4.2	18.0	2.9	2.6	21.7	11.6	6.5	2.5	1.0	4.3	2.8	5.7
	(0.5)	(1.1)	(0.5)	(0.5)	(1.1)	(0.9)	(0.7)	(0.5)	(0.3)	(0.6)	(0.5)	(0.8)
East Northern Mountain	10.5	10.0	13.4	17.2	9.3	13.9	13.0	10.2	5.8	13.0	10.5	18.0
	(1.0)	(1.0)	(1.1)	(1.2)	(1.0)	(1.2)	(1.1)	(1.0)	(0.8)	(1.2)	(1.1)	(1.3)
West Northern Mountain	16.3	18.9	19.5	19.7	17.8	12.5	29.7	17.9	26.2	24.3	10.0	35.1
	(2.4)	(2.5)	(2.7)	(2.6)	(2.3)	(1.9)	(3.0)	(2.4)	(2.8)	(2.6)	(1.9)	(2.9)
North Central Coast	16.7	37.9	23.9	29.6	11.2	32.3	47.8	36.2	10.6	14.8	9.9	47.3
	(1.0)	(1.9)	(1.6)	(1.8)	(1.3)	(1.9)	(2.0)	(1.9)	(1.2)	(1.4)	(1.3)	(2.0)
South Central Coast	20.2	18.7	15.6	36.5	32.7	37.2	57.7	63.9	12.1	25.9	14.3	20.7
	(1.8)	(1.8)	(1.3)	(2.2)	(2.1)	(2.2)	(2.3)	(2.2)	(1.5)	(2.0)	(1.6)	(1.8)
Central Highlands	18.2	17.5	13.0	42.2	14.4	30.9	29.6	26.1	33.9	49.5	16.6	23.4
	(2.2)	(2.1)	(2.0)	(2.7)	(2.1)	(2.6)	(2.7)	(2.4)	(2.7)	(2.8)	(2.2)	(2.3)
South East	17.5	9.9	10.9	12.5	7.8	5.0	8.3	6.4	7.9	12.9	2.5	13.4
	(1.6)	(1.3)	(1.4)	(1.4)	(1.0)	(1.0)	(1.3)	(1.0)	(1.1)	(1.5)	(0.8)	(1.6)
Mekong Delta	14.7	14.9	16.5	16.8	4.3	5.6	1.5	2.7	2.3	1.9	1.4	3.2
	(1.0)	(1.0)	(1.1)	(1.1)	(0.6)	(0.7)	(0.4)	(0.4)	(0.4)	(0.4)	(0.3)	(0.5)
Geographic types												
Coastal	13.6	34.2	21.0	29.1	14.2	26.7	23.0	21.1	5.9	14.5	7.2	15.5
	(1.9)	(2.5)	(2.0)	(2.4)	(1.8)	(2.3)	(2.2)	(2.3)	(1.2)	(1.8)	(1.5)	(2.1)
Delta	9.5	17.9	10.3	15.1	16.2	12.8	13.2	11.6	3.1	5.6	4.0	9.9
	(0.5)	(0.7)	(0.6)	(0.7)	(0.7)	(0.6)	(0.6)	(0.6)	(0.3)	(0.4)	(0.4)	(0.6)
Midlands/hill	12.2	10.5	12.6	13.6	9.4	10.9	20.9	18.4	7.8	12.9	3.6	22.8
	(1.7)	(1.7)	(1.6)	(1.8)	(1.5)	(1.6)	(2.1)	(2.3)	(1.4)	(1.7)	(1.0)	(2.5)
Low mountains	17.1	17.6	17.0	21.9	12.9	20.4	27.8	17.7	15.5	20.0	13.1	28.3
	(1.3)	(1.3)	(1.2)	(1.3)	(1.2)	(1.3)	(1.5)	(1.2)	(1.3)	(1.3)	(1.1)	(1.5)
High mountains	19.4	20.1	17.1	23.4	13.7	23.1	31.2	26.1	22.0	29.2	11.1	28.5
	(1.4)	(1.6)	(1.4)	(1.5)	(1.2)	(1.6)	(1.7)	(1.5)	(1.5)	(1.6)	(1.1)	(1.5)
All rural Vietnam	11.6	18.7	12.9	18.4	13.7	16.3	18.9	15.8	7.6	12.5	6.5	17.0
	(0.4)	(0.5)	(0.4)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(0.4)	(0.4)	(0.4)	(0.5)

Note: Standard errors are in parentheses.
Source: Authors' estimation from the VHLSSs 2004, 2006, 2008 and 2010.

Table 3: The percentage of population living in communes affected disasters by ethnic minorities and expenditure quintiles

	The percentage of population living in communes affected by storms				The percentage of population living in communes affected by floods				The percentage of population living in communes affected by droughts			
	2004	2006	2008	2010	2004	2006	2008	2010	2004	2006	2008	2010
Ethnic minorities												
Kinh/Hoa	10.3	18.6	12.7	16.7	13.8	15.5	18.0	14.7	5.5	10.3	5.8	14.9
	(0.4)	(0.6)	(0.5)	(0.6)	(0.5)	(0.5)	(0.6)	(0.5)	(0.3)	(0.5)	(0.4)	(0.6)
Ethnic minorities	18.3	19.2	14.2	25.8	12.6	20.1	23.4	20.7	18.6	22.9	9.8	26.1
	(1.3)	(1.4)	(1.2)	(1.3)	(1.1)	(1.4)	(1.4)	(1.3)	(1.3)	(1.4)	(1.0)	(1.4)
Expenditure quintile												
Poorest	13.4	20.8	13.9	23.5	13.7	22.2	21.6	20.1	12.6	17.6	8.2	22.5
	(0.9)	(1.2)	(0.9)	(1.2)	(0.9)	(1.2)	(1.1)	(1.1)	(0.9)	(1.1)	(0.8)	(1.2)
Near poorest	11.9	21.5	13.6	18.7	16.8	16.7	21.1	17.5	6.5	11.8	7.1	18.2
	(0.9)	(1.2)	(0.9)	(1.1)	(1.0)	(1.1)	(1.2)	(1.1)	(0.7)	(0.9)	(0.8)	(1.1)
Middle	9.9	17.5	12.9	16.2	13.9	16.6	17.8	15.8	6.6	11.7	4.8	14.8
	(0.8)	(1.1)	(1.0)	(1.1)	(0.9)	(1.1)	(1.1)	(1.1)	(0.7)	(0.9)	(0.6)	(1.1)
Near richest	11.8	16.0	12.0	16.1	10.9	11.8	17.1	11.0	5.3	9.8	6.5	13.8
	(1.0)	(1.1)	(1.0)	(1.1)	(0.9)	(1.0)	(1.2)	(0.9)	(0.6)	(0.9)	(0.9)	(1.1)
Richest	9.4	14.3	10.8	13.7	9.8	7.7	13.2	9.6	3.3	7.6	4.5	10.8
	(1.2)	(1.4)	(1.1)	(1.3)	(1.3)	(1.0)	(1.3)	(1.1)	(0.8)	(1.0)	(0.8)	(1.3)
All rural Vietnam	11.6	18.7	12.9	18.4	13.7	16.3	18.9	15.8	7.6	12.5	6.5	17.0
	(0.4)	(0.5)	(0.4)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(0.4)	(0.4)	(0.4)	(0.5)

Note: Standard errors are in parentheses.
Source: Authors' estimation from the VHLSSs 2004, 2006, 2008 and 2010.

4. Estimation methods

4.1. Effects on natural disasters on household welfare

The main estimation method used in this study is econometric regression. We assume a household welfare indicator is a function of characteristics of households and communities as follows (Glewwe, 1991):

$$\ln(Y_{ijt}) = \beta_0 + X_{ijt}\beta_1 + C_{jt}\beta_2 + D_{jt}\beta_3 + X_{ijt}D_{jt}\beta_4 + C_{jt}D_{jt}\beta_5 + G_t\beta_6 + \varepsilon_{ijt}, \quad (1)$$

where Y_{ijt} is an welfare indicator of household *i* in commune *j* in the year *t*; X_{ijt} is a vector of characteristics of households such as demographical variables and assets; C_{jt} is a vector of characteristics of communities such as infrastructure; D_{jt} is a vector of three dummy variables indicating whether storms, floods and droughts happened in communes during the past two years; G_t is the dummy variable of years; ε_{ijt} is unobserved variables.

We use different indicators of household welfare including per capita income, per capita expenditure, the poverty status of households, and share of incomes by different sources. We use similar specifications as equation (1) for different dependent variables.

The effect of natural disaster on households is measured by parameters β_3, β_4 and β_5. The effect of disasters also reflects the resilience level of households. Households with more resilience to disasters are less affected by disasters. The equation (1) includes interactions between the natural disasters and variables of communes and households. It allows the effect of natural disasters to vary across different households.

A problem is estimating the effect of natural disasters is the endogeneity of natural disasters. The unobserved variables can be correlated with the disaster variables. In equation (1), unobserved variables ε_{ijt} include both commune-level and household-level

variables. Since our disaster variables are the commune-level variables, they are more likely to be correlated with unobserved commune-level variables. The unobserved commune-level variables can be decomposed into time-variant and time-invariant commune-level variables.In this study, we use the commune fixed-effect regression to eliminate unobserved time-invariant commune-level variables. It is expected that the endogeneity bias will be negligible after the elimination of these unobserved time-invariant variables and the control of observed variables. In addition, the natural shocks are expected more exogenous than social economic shocks.[5]

The equation (1) includes interactions between the natural disaster variable and variables of communes and households. It allows the effect of natural disasters to vary across different households. Households who are more resilient to natural disasters are less likely to be affected by natural disasters. In this study, we interact the disasters variables with a large number of household and commune variables to examine whether the effect of disasters varies across these variables.

4.2. Geographic effects of natural disasters on household expenditure

In this study, we will measure the effect of disasters on household welfare at provincial and district levels. From model (1), the partial effect of a disaster on log of per capita expenditure is estimated by taking partial derivative of the dependent variable with respect to the disaster variable:

$$PE_{\log(Y)\_ijt} = \beta_3 + X_{ijt}\beta_4 + C_{jt}\beta_5. \qquad (2)$$

This effect varies across households, communes and years. Since the dependent variable is measured in logarithm, $PE_{\log(Y)\_ijt}$ is interpreted as the percentage change in per capita expenditure of household *i* if their commune is exposed to disasters.To measure the partial effect of the natural disasters on the absolute value of per capita expenditure, we can take

[5]A better approach is to use household fixed-effect regressions. However, this approach requires panel data at the household level, and there are no household panel data from the 2004 VHLSS to the 2010 VHLSS.

the partial derivative of per capita expenditure with respect to the disaster variable as follows:

$$PE_{Y\_ijt} = \frac{\partial Y_{ijt}}{\partial D_{jt}} = \frac{\partial e^{\beta_0 + X_{ijt}\beta_1 + C_{jt}\beta_2 + D_{jt}\beta_3 + X_{ijt}D_{jt}\beta_4 + C_{jt}D_{jt}\beta_5 + G_t\beta_6 + u_{ij} + \varepsilon_{ijt}}}{\partial D_{jt}}$$
$$= \left(\beta_3 + X_{ijt}\beta_4 + C_{jt}\beta_5\right) e^{\beta_0 + X_{ijt}\beta_1 + C_{jt}\beta_2 + D_{jt}\beta_3 + X_{ijt}D_{jt}\beta_4 + C_{jt}D_{jt}\beta_5 + G_t\beta_6 + u_{ij} + \varepsilon_{ijt}} \quad (3)$$
$$= \left(\beta_3 + X_{ijt}\beta_4 + C_{jt}\beta_5\right) Y_{ijt}.$$

We can take the average of this partial effect across households within an area such a province or a district to compute the average partial effect of disasters for that area. Because the VHLSSs are sampled surveys which are not representative for provinces as well as smaller areas, we will use the Agriculture and Fishery Census 2006 (RAFC) to estimate the effect of disasters at small areas.[6]The estimated effects are interpreted for the year 2006.

For an area*K*, the estimator is expressed as follows:

$$\hat{APE}_{Log(Y)\_K} = \frac{1}{n_K}\sum_{k\in K}(\hat{\beta}_3 + X_k^{RAFC}\,\hat{\beta}_4 + C_k^{RAFC}\,\hat{\beta}_5), \qquad (4)$$

where $\hat{\beta}_3$, $\hat{\beta}_4$ and $\hat{\beta}_5$ are estimates from the model (1), n_K is the number of people in area*K*. The upper-subscript 'RAFC' means the household and commune variables from the 2006 RAFC. The standard error of $\hat{APE}_K$ can be easily obtained by a delta method. $\hat{APE}_{Log(Y)\_K}$ is interpreted as the percentage change in the average per capita expenditure of area *K* if a disaster happens in that area. We can also estimate the average partial effect of disasters on the absolute value of per capita expenditure for district *K*by taking the average of PE_{Y_ijt} in equation (3) across population in district *K*:

$$\hat{APE}_{Y\_K} = \frac{1}{n_K}\sum_{k\in K}(\hat{\beta}_3 + X_k^{RAFC}\,\hat{\beta}_4 + C_k^{RAFC}\,\hat{\beta}_5)Y_k \qquad (5)$$

[6]The Rural Agriculture and Fishery Census (RAFC) was carried out by the GSO in 2006. The censuses covered all households in rural areas. The censuses contain data on individuals and households including basic demography, employment and housing, and agricultural activities. There are also commune-level data on socio-economic conditions, agricultural production, infrastructure and transportation, education, health, and social affairs, natural disasters affecting households of all the rural communes throughout the country.

The average partial effect can be estimated for all small areas such as districts or communes. In some areas, there are no disasters in recent years. Thus, $\hat{APE}_{Log(Y)\_K}$ and $\hat{APE}_{Y\_K}$ are not measures of the actual loss caused by disasters. It can be regarded as the measures of the potential loss for an area if there is a disaster happens in that area. In this study, we will estimate $\hat{APE}_{Log(Y)\_K}$ and $\hat{APE}_{Y\_K}$ for all the districts and provinces of the country. Districts or provinces with high value of $\hat{APE}$ are more likely affected by disasters if the disasters happen in these districts and provinces. High value of $\hat{APE}$ also means low resilience to disasters.

It should be noted that we cannot estimate the potential loss of districts or provinces using data only from the VHLSSs. These surveys are not representative at the district and province level. On the other hand, we cannot use data from only the 2006 RAFC to estimate model (1), since the 2006 RAFC does not contain data on household income and consumption expenditure.[7] Thus we have to combine the VHLSSs and the 2006 RAFC to estimate the potential loss in household income caused by natural disaster at the commune level. It is worth noting that we have to limit the explanatory variables in model (1) to those that are available in both the VHLSSs and the 2006 RAFC in order to apply the predicted model of the effect of natural disasters on household income into the 2006 RAFC.[8]

5. Empirical results

5.1. The effect of natural disasters on household welfare

[7]To estimate in equation (5) which contains per capita expenditure of households in districts, we have to use the predicted per capita expenditure of households that is estimated from small area estimation method using data from the 2006 VHLSS and the 2006 RAFC. We obtained the predicted expenditure data from Nguyen et al. (2010).

[8]The method to combine household survey and censes is called the small area estimation method. Elbers et al. (2002, 2003) develop this method to estimate the poverty and welfare indexes at the small areas. In Vietnam, it has been widely applied to construct the poverty maps (e.g., Nguyen et al., 2010; Nguyen, 2011).

In Table 4, we present the commune fixed-effects regression of log of per capita income, log of per capita expenditure and the poverty status of households. We used two models which differ in the number of explanatory variables to examine the sensitivity of the estimates of disaster impacts to the selection of explanatory variables. The small model contains only disaster variables and demographical variables. The large models include additional variables of education, land, living area, and commune infrastructures. We tend to use a small set of control variables that are more exogenous or less likely to be affected by natural disasters. The control variables should not be affected by the treatment variable of interest, i.e., the disasters in this study (Heckman and others, 1999; Angrist and Pischke, 2008). The summary statistics of dependent variables and explanatory variables is presented in Table A.1 in Appendix.

All the three disaster types (storms, floods and droughts) have a negative effect on household welfare. The effect of storms tends to be smaller than the effect of floods and droughts. According to the large models in Table 4, per capita income of households living in a commune with storms, floods and droughts decreases approximately by 1.9%, 5.9%, and 5.2%, respectively. Storms, floods and drought also have an expenditure reducing effect, by 1.5%, 4.4%, and 3.5% on average, respectively. Since disasters reduce per capita expenditure, they increase the expenditure poverty rate. All the three disaster variables have positive signs in the regressions of poverty. However, only the effect of floods on the probability of being poor is statistically significant in the large model. Living in a commune with floods during the past two years can increase the probability of being poor 0.018.

Table 4 also reportsthe estimated coefficients on household and community characteristics, and these estimated coefficients have expected signs. More specifically, households with larger size and lower proportion of working-age people tend to have lower per capita income and expenditure. Ethnic minority households and households with female and older heads also have lower per capita income and expenditure. The more educated households with more crop land and living areas are more likely to have higher per capita income and expenditure and lower poverty. Commune roads, markets and firms are positively correlated with household income and expenditure. The year dummies suggest that household income and expenditure increased over the period 2004-2010.

Table 4: Commune fixed-effects regressions of household outcomes

Explanatory variables	Log of per capita income		Log of per capita expenditure		Poverty status (Poor=1, Non-Poor=0)	
	Small model	Large model	Small model	Large model	Small model	Large model
Commune affected by storm	-0.0066	-0.0192*	-0.0101	-0.0154*	0.0055	0.0071
	(0.0110)	(0.0106)	(0.0088)	(0.0083)	(0.0065)	(0.0068)
Commune affected by flood	-0.0479***	-0.0586***	-0.0389***	-0.0435***	0.0107*	0.0184***
	(0.0110)	(0.0105)	(0.0088)	(0.0083)	(0.0065)	(0.0067)
Commune affected by drought	-0.0575***	-0.0524***	-0.0397***	-0.0352***	0.0146*	0.0132
	(0.0134)	(0.0127)	(0.0107)	(0.0100)	(0.0078)	(0.0081)
Household size	-0.0638***	-0.0141***	-0.0712***	-0.0310***	0.0325***	0.0209***
	(0.0021)	(0.0024)	(0.0017)	(0.0019)	(0.0013)	(0.0016)
Proportion of adults from 15 to 60 in households	0.5258***	0.3646***	0.4532***	0.3012***	-0.2387***	-0.1852***
	(0.0125)	(0.0133)	(0.0099)	(0.0104)	(0.0077)	(0.0089)
Ethnic minorities	-0.4700***	-0.4189***	-0.4397***	-0.3755***	0.3354***	0.3061***
	(0.0124)	(0.0121)	(0.0100)	(0.0096)	(0.0069)	(0.0075)
Age of household head		-0.0013***		-0.0004*		0.0000
		(0.0003)		(0.0002)		(0.0002)
Gender of household head (female=1, male=0)		-0.0856***		-0.0655***		0.0459***
		(0.0089)		(0.0070)		(0.0060)
Proportion of members with upper-secondary degree		0.3628***		0.5488***		-0.2031***
		(0.0231)		(0.0181)		(0.0155)
Proportion of member with college/university		0.9238***		0.7124***		-0.1928***
		(0.0209)		(0.0164)		(0.0140)
Crop land area (1000 m2)		0.0425***		0.0204***		-0.0064***
		(0.0013)		(0.0010)		(0.0009)
Per capita living area (m2)		0.0133***		0.0120***		-0.0037***
		(0.0003)		(0.0003)		(0.0002)
Commune with road passable all 12 months		0.0365***		0.0504***		-0.0384***
		(0.0104)		(0.0082)		(0.0066)
Commune with irrigation system		-0.0201		-0.0092		0.0012
		(0.0190)		(0.0070)		(0.0056)
Commune with a market		0.0577***		0.0427***		-0.0231***
		(0.0094)		(0.0074)		(0.0059)
Commune with firms		0.0724***		0.0523***		-0.0317***
		(0.0088)		(0.0069)		(0.0055)
Year 2006	0.1653***	0.1532***	0.1311***	0.1184***	-0.0390***	-0.0306***
	(0.0089)	(0.0102)	(0.0070)	(0.0080)	(0.0056)	(0.0069)
Year 2008	0.2627***	0.2140***	0.2632***	0.2135***	-0.0499***	-0.0267***
	(0.0089)	(0.0102)	(0.0071)	(0.0080)	(0.0056)	(0.0069)
Year 2010	0.4099***	0.3197***	0.5199***	0.4467***	-0.0548***	-0.0323***
	(0.0127)	(0.0132)	(0.0103)	(0.0104)	(0.0070)	(0.0082)
Constant	8.3388***	7.8906***	8.1346***	7.7130***	0.1809***	0.3292***
	(0.0148)	(0.0260)	(0.0118)	(0.0204)	(0.0088)	(0.0171)
Observations	27,404	27,404	27,407	27,404	27,407	27,404
R-squared	0.131	0.293	0.188	0.352	0.0616	0.0841
Number of communes	4,629	4,629	4,629	4,629	4,629	4,629

Note: *** p<0.01, ** p<0.05, * p<0.1
Robust standard errors are in parentheses.
Source: Authors' estimation from the VHLSSs 2004, 2006, 2008 and 2010.

Natural disasters can affect household livelihood. Households might be more diversified and invest more into low-risk and low-return production when facing high risks (Rosenzweig and Binswanger, 1993; Morduch, 1995; Thomas et al., 2010; Van den Berg, 2010). In Table 5, we examine the effect of natural disasters on the income share from different income sources. Since disasters can have immediate adverse effects on agriculture, we expect that households might move from farm to non-farm activities due to disasters. However, this hypothesis is not strongly supported by empirical evidences from this study. Overall, the effect of disasters on income structure of household is small. Households in communes with storms have the share of 'other farm income' in the total income about 0.7 percentage point higher than households in communes without storms. In this paper, 'other farm income' includes income from aquaculture, forestry, hunting and other agriculture services.

Floods and droughts increase the share of livestock income of household by around 1.0 and 0.7 percentage points, respectively. However, households in communes more exposed to droughts have lower shares of 'other farm income' and nonfarm wages.The positive effect of droughts on livestock is also found in Kinsey et al. (1998) for the case of Zimbabwe. Households raise livestock because of its liquidity for consumption smooth in case of income shocks.

Table 5 implies the role of the access to roads, markets and enterprises in increasing non-farm incomes. Households in communes with better infrastructure and more enterprises tend to have higher shares of wage and non-farm incomes.

Table 5: Commune fixed-effects regressions of income shares

Explanatory variables	Share of crop income	Share of livestock income	Share of other farm income	Share of wage income	Share of non-farm income	Share of other income
Commune affected by storm	-0.1423	0.2619	0.6979**	-0.9635	-0.3987	0.0038
	(0.4409)	(0.2391)	(0.3058)	(0.5804)	(0.4531)	(0.4052)
Commune affected by flood	0.1194	0.9992***	-0.1884	-0.3808	-0.1610	-0.6155
	(0.4378)	(0.2367)	(0.3039)	(0.5448)	(0.4482)	(0.3997)
Commune affected by drought	0.8693	0.6887**	-0.6435*	0.8017	-1.4112***	-0.0447
	(0.5316)	(0.2849)	(0.3708)	(0.6560)	(0.5394)	(0.4805)
Household size	0.5994***	0.0251	0.4526***	1.1721***	0.8919***	-3.1691***

Explanatory variables	Share of crop income	Share of livestock income	Share of other farm income	Share of wage income	Share of non-farm income	Share of other income
	(0.0979)	(0.0562)	(0.0664)	(0.1290)	(0.1069)	(0.0985)
Proportion of adults from 15 to 60 in households	4.8948***	1.9949***	1.1989***	10.7857***	0.1963	-19.087***
	(0.5356)	(0.3097)	(0.3628)	(0.7109)	(0.5896)	(0.5459)
Ethnic minorities	9.6321***	1.4869***	4.1591***	-7.6312***	-8.4659***	0.0588
	(0.5207)	(0.2659)	(0.3706)	(0.6133)	(0.5017)	(0.4363)
Age of household head	0.0310***	-0.0234***	-0.0414***	-0.2006***	-0.2174***	0.4607***
	(0.0107)	(0.0062)	(0.0073)	(0.0142)	(0.0118)	(0.0109)
Gender of household head (female=1, male=0)	-2.5732***	-1.5268***	-1.8683***	4.0164***	-0.5150	2.7524***
	(0.3593)	(0.2078)	(0.2433)	(0.4769)	(0.3955)	(0.3662)
Proportion of members with upper-secondary degree	-5.4687***	1.5165***	-3.5958***	-6.0910***	6.7756***	7.3905***
	(0.9314)	(0.5373)	(0.6314)	(1.2333)	(1.0226)	(0.9460)
Proportion of member with college/university	-23.087***	-4.7298***	-5.9002***	33.9471***	-3.6467***	4.7626***
	(0.8420)	(0.4844)	(0.5713)	(1.1120)	(0.9217)	(0.8507)
Crop land area (1000 m2)	3.0587***	0.0220	-0.1702***	-1.5562***	-0.7945***	-0.5938***
	(0.0544)	(0.0306)	(0.0372)	(0.0704)	(0.0582)	(0.0532)
Per capita living area (m2)	-0.0472***	0.0185**	0.0290***	-0.3512***	0.1225***	0.2387***
	(0.0134)	(0.0077)	(0.0091)	(0.0178)	(0.0147)	(0.0136)
Commune with road passable all 12 months	-2.9237***	0.3536	-3.0723***	3.6056***	2.7178***	0.4043
	(0.4397)	(0.2322)	(0.3080)	(0.5351)	(0.4391)	(0.3871)
Commune with irrigation system	1.0568***	0.7425***	-0.6966***	-0.7125	-0.2742	-0.2192
	(0.3780)	(0.1985)	(0.2653)	(0.4575)	(0.3752)	(0.3295)
Commune with a market	-2.9568***	-1.9457***	-0.6947**	1.5694***	5.1813***	-0.7336**
	(0.3969)	(0.2100)	(0.2777)	(0.4838)	(0.3971)	(0.3499)
Commune with firms	-1.7585***	-0.8741***	-0.3546	2.6472***	1.5408***	-0.7283**
	(0.3687)	(0.1955)	(0.2579)	(0.4504)	(0.3698)	(0.3268)
Year 2006	-0.4155	-0.0006	0.1325	3.9929***	0.9979**	-4.8894***
	(0.4065)	(0.2383)	(0.2742)	(0.5465)	(0.4541)	(0.4242)
Year 2008	-0.4376	-0.6194***	-0.4541*	3.7570***	-0.2529	-2.3295***
	(0.4075)	(0.2388)	(0.2748)	(0.5478)	(0.4551)	(0.4249)
Year 2010	1.3699**	-1.5810***	-0.3926	9.5463***	-0.5357	-8.5595***
	(0.5677)	(0.2898)	(0.4096)	(0.6680)	(0.5476)	(0.4841)
Constant	21.792***	8.2061***	9.9030***	21.682***	14.918***	22.136***
	(1.0668)	(0.5952)	(0.7349)	(1.3679)	(1.1304)	(1.0307)
Observations	27,404	27,404	27,407	27,404	27,407	27,404
R-squared	0.145	0.0118	0.0126	0.122	0.0339	0.268
Number of communes	4,629	4,629	4,629	4,629	4,629	4,629

Note: The income share is measure in percent. 'Other farm income' includes income from aquaculture, forestry, hunting and agriculture services.
Note: *** p<0.01, ** p<0.05, * p<0.1
Robust standard errors are in parentheses.
Source: Authors' estimation from the VHLSSs 2004, 2006, 2008 and 2010.

5.2. Resilience to disasters

To examine which household and commune variables can help household mitigate the adverse effect of disasters, we include the interactions between disasters and household

variables in the regressions of log of per capita expenditure. In this section we use consumption expenditure instead of income as the dependent variable, since consumption expenditure is widely used as an aggregate indicator of household welfare and expenditure data contain less measurement errors than income data.

In each regression, we include only one interaction between a disaster variable and an interacted variable. We also control for other disaster variables and explanatory variables (as presented in the large model in Tables 4 and 5). We do not include all interaction terms and the interacted variables in one regression, since it can result in the multicollinearity problem and high standard errors of these interactions. In Table 6, we present only the estimated coefficient of the interactions. For example, the estimate -0.0110 in the upper-left cell of Table 6 is the estimated coefficient of the interaction between household size and the storm variable in the regression of log of per capita expenditure. There are three disaster variables which are interacted in turn with ten household-level variables. Thus there are 30 regressions, and the estimated coefficients of 30 interactions are presented in Table 6.

The effect of storms tends to be higher for households with larger size. This implies that households with a smaller number of members are more resilient to storm. However, the effect of floods and droughts does not vary significantly across households with different household size. Households with a higher proportion of working-age members are more resilient to disasters. This finding is as our expectation since households who suffer from adverse shocks tend to increase labor supply to mitigate the income and consumption loss (Kochar, 1999; Rose, 2001).

Ethnic minorities are more vulnerable to storms than Kinh/Hoa. Possibly, ethnic minority households face more credit constraints and have fewer assets to smooth consumptions. Households with high education are less affected by floods and droughts than those with low education. Households with larger croplands tend to more resilient to droughts but not storms and floods.

Micro-credit and transfers are very important for household to increase income and consumption. In Vietnam, several studies find positive effects of micro-credit and transfers on household welfare (e.g., Quach and Mullineux, 2007;Nguyen, 2008; Van den Berg and

Nguyen, 2011; Nguyen, 2013). Credit and transfers can help households who are affected by natural disasters smooth their consumption(Sawada, 2006). For the case of Vietnam, households with micro-credit, internal remittances and social allowances tend to be more resilient to natural disasters (Table 6).[9]Access to these financial sources can mitigate the adverse effect of disasters on household expenditure.

Table 6: Interaction terms between disaster variables and household variables in commune fixed-effects regressions of log of per capita expenditure

Interacted variables	Interactions between the **storm** variable and other variables	Interactions between the **flood** variable and other variables	Interactions between the **drought** variable and other variables
Household size * Disaster variable	-0.0110***	-0.0042	0.0015
	(0.0042)	(0.0041)	(0.0048)
Proportion of adults from 15 to 60 in households * Disaster variable	0.0289	0.0706***	0.0805***
	(0.0257)	(0.0247)	(0.0305)
Ethnic minorities * Disaster variable	-0.0757***	0.0043	0.0156
	(0.0201)	(0.0197)	(0.0210)
Proportion of members with upper-secondary degree * Disaster variable	0.0381	0.0797*	-0.0074
	(0.0468)	(0.0440)	(0.0539)
Proportion of member with college/university * Disaster variable	0.0516	0.0458	0.1054**
	(0.0448)	(0.0428)	(0.0525)
Crop land area (1000 m2) * Disaster variable	-0.0039	0.0091**	0.0053
	(0.0025)	(0.0036)	(0.0036)
Micro-finance from Vietnam Bank for Social Policies (million VND) * Disaster variable	0.0049	0.0078***	0.0056*
	(0.0030)	(0.0029)	(0.0031)
International remittances (million VND) * Disaster variable	0.0011	0.0048***	-0.0005
	(0.0012)	(0.0015)	(0.0023)
Internal remittances (million VND) * Disaster variable	0.0069***	0.0061***	0.0057**
	(0.0018)	(0.0022)	(0.0025)
Social allowances (million VND) * Disaster variable	0.0050	0.0141***	0.0088*
	(0.0047)	(0.0043)	(0.0046)

Note: *** p<0.01, ** p<0.05, * p<0.1
Robust standard errors are in parentheses.
This table presents estimates of interactions between disaster variables and different explanatory variables.
Source: Authors' estimation from the VHLSSs 2004, 2006, 2008 and 2010.

Table 7 presents the estimates of the interactions between the disaster variables and commune-level variables. Overall, the commune infrastructures are not very important in reducing the effect of natural disasters on household welfare. Households in communes

[9] Micro-credit in Vietnam is mainly provided by the Vietnam Bank for Social Policies. For analysis of micro-credit in Vietnam, see Nguyen (2009).

with road are more resilient to storms but not floods and drought. Meanwhile, households in commune with irrigation systems tend to be more resilient to floods but not storms and drought.

We interact the disaster variables with mean expenditure and expenditure Gini index of communes. Data on the mean expenditure and Gini at the commune level are available only in 2006.[10] Interactions between commune mean expenditure and all the three disaster variables are positive and statistically significant. It implies that households in better-off areas are more resilient to natural disasters. This is also hypothesized in Greiving (2006) and Greiving et al. (2006) that households in better-off regions have higher coping capacity to natural disasters.

The impact of natural disasters on household welfare might be more severe if income redistribution is not appropriately conducted (Fothergill and Peek, 2004; Wisner et al. 2004). Table 7 shows that households living in communes with high expenditure inequality tend to be more affected by floods and droughts. Put it differently, reducing expenditure inequality might help households strengthen their resilience to floods and droughts.

Table 7: Interaction terms between disaster variables and commune variables in commune fixed-effects regressions of log of per capita expenditure

Interacted variables	Interactions between the **storm** variable and other variables	Interactions between the **flood** variable and other variables	Interactions between the **drought** variable and other variables
Communes with firms * Disaster variable	-0.0098	-0.0122	-0.0198
	(0.0165)	(0.0163)	(0.0192)
Commune with road passable all 12 months * Disaster variable	0.0538***	-0.0203	-0.0266
	(0.0206)	(0.0207)	(0.0233)
Commune with irrigation system * Disaster variable	-0.0015	0.0028***	0.0007
	(0.0016)	(0.0008)	(0.0015)
Proportion of villages in commune with national electricity grid * Disaster variable	0.0318	-0.0789	-0.0717
	(0.0457)	(0.0486)	(0.0496)
Number of markets in commune * Disaster variable	0.0042	0.0064	-0.0027
	(0.0101)	(0.0094)	(0.0114)

[10] We obtain the commune data on mean expenditure and Gini from Nguyen et al. (2010). Commune-level data on expenditure are estimated by using the small area estimation method and data from the 2006 VHLSS and the 2006 RAFC (Nguyen et al., 2010).

Interacted variables	Interactions between the **storm** variable and other variables	Interactions between the **flood** variable and other variables	Interactions between the **drought** variable and other variables
Population of commune (thousand VND) * Disaster variable	0.0028	-0.0009	-0.0038
	(0.0021)	(0.0022)	(0.0026)
Mean per capita expenditure of commune (million VND) * Disaster variable	0.0244***	0.0143**	0.0094*
	(0.0074)	(0.0064)	(0.0051)
Gini index of per capita expenditure of commune (million VND) * Disaster variable	-0.0575	-0.5583**	-0.7618***
	(0.2536)	(0.2707)	(0.2796)

Note: *** p<0.01, ** p<0.05, * p<0.1
Robust standard errors are in parentheses.
This table presents estimates of interactions between disaster variables and different explanatory variables.
Source: Authors' estimation from the VHLSSs 2004, 2006, 2008 and 2010.

5.3. Geographical effects of natural disasters

To examine the geographically heterogeneous effect of disasters, we include all the interactions between the disaster variables and interacted variables in one regressions and using the stepwise backward selection. Interactions with the 10% significant level are kept in the model. Table 8 presents the final model of log of per capita expenditure with interaction variables. Interactions between the mean per capita expenditure of communes and the three disaster variables are all positive and statistically significant.

Table 8: Commune fixed-effects regressions of log of per capita expenditure with interactions

Explanatory variables	Log of per capita expenditure: including interactions between storms and other variables	Log of per capita expenditure: including interactions between floods and other variables	Log of per capita expenditure: including interactions between droughts and other variables
Commune affected by storm	-0.2619***	-0.0184**	-0.0199**
	(0.0403)	(0.0087)	(0.0087)
Commune affected by flood	-0.0398***	-0.3800***	-0.0407***
	(0.0085)	(0.0467)	(0.0086)
Commune affected by drought	-0.0279***	-0.0313***	-0.4034***

Explanatory variables	Log of per capita expenditure: including interactions between storms and other variables	Log of per capita expenditure: including interactions between floods and other variables	Log of per capita expenditure: including interactions between droughts and other variables
	(0.0104)	(0.0104)	(0.0504)
Proportion of adults from 15 to 60 * Commune affected by flood		0.0691***	
		(0.0256)	
Ethnic minorities * Commune affected by flood		0.0904***	
		(0.0248)	
Crop land area (1000 m2) * Commune affected by flood		0.0097**	
		(0.0039)	
Population of commune (thousand VND) * Commune affected by flood		0.0042*	
		(0.0023)	
Population of commune (thousand VND) * Commune affected by flood		0.0582***	
		(0.0104)	
Household size * Commune affected by storm	-0.0077*		
	(0.0044)		
Crop land area (1000 m2) * Commune affected by storm	-0.0043*		
	(0.0026)		
Commune with road passable all 12 months * Commune affected by storm	0.0488**		
	(0.0202)		
Population of commune (thousand VND) * Commune affected by storm	0.0578***		
	(0.0077)		
Proportion of adults from 15 to 60 * Commune affected by drought			0.0677**
			(0.0316)
Ethnic minorities * Commune affected by drought			0.0762***
			(0.0257)
Crop land area (1000 m2) * Commune affected by drought			0.0130***
			(0.0045)
Population of commune (thousand VND) * Commune affected by drought			0.0617***
			(0.0105)
Control variables	Yes	Yes	Yes
Constant	7.7083***	7.7245***	7.7176***
	(0.0218)	(0.0218)	(0.0217)
Observations	27,404	27,404	27,407
R-squared	0.352	0.351	0.352
Number of communes	4,629	4,629	4,629

Note: *** p<0.01, ** p<0.05, * p<0.1
Robust standard errors are in parentheses.
Source: Authors' estimation from the VHLSSs 2004, 2006, 2008 and 2010.

Table 9 presents the estimated effect of the disasters on log of per capita expenditure and per capita expenditure by regions (using estimators presented in equations (4) and (5)). The effect of storms on is highest in West Northern Mountains, and second highest in Central Highland. In other words, these two regions are the least resilient to storms. Although Central Coast is more exposed to storms than West Northern Mountains and Central Highlands, the effect of storms is smaller in Central Coast than in West

Northern Mountains and Central Highlands. South East is the least affected by storms. Mekong River Delta and Red River Delta are also regions which are less affected by storms.

North Central Coast is the region which is most effected by both floods and droughts. Other poor regions such as Northern Mountains and Central Highland are also more likely to be affected by floods. South East is the least affected by floods and storms, because this is regions is the richest and the effect of disasters decreases as the mean expenditure increased.

Table 9: The effect of disasters on log of per capita income by regions

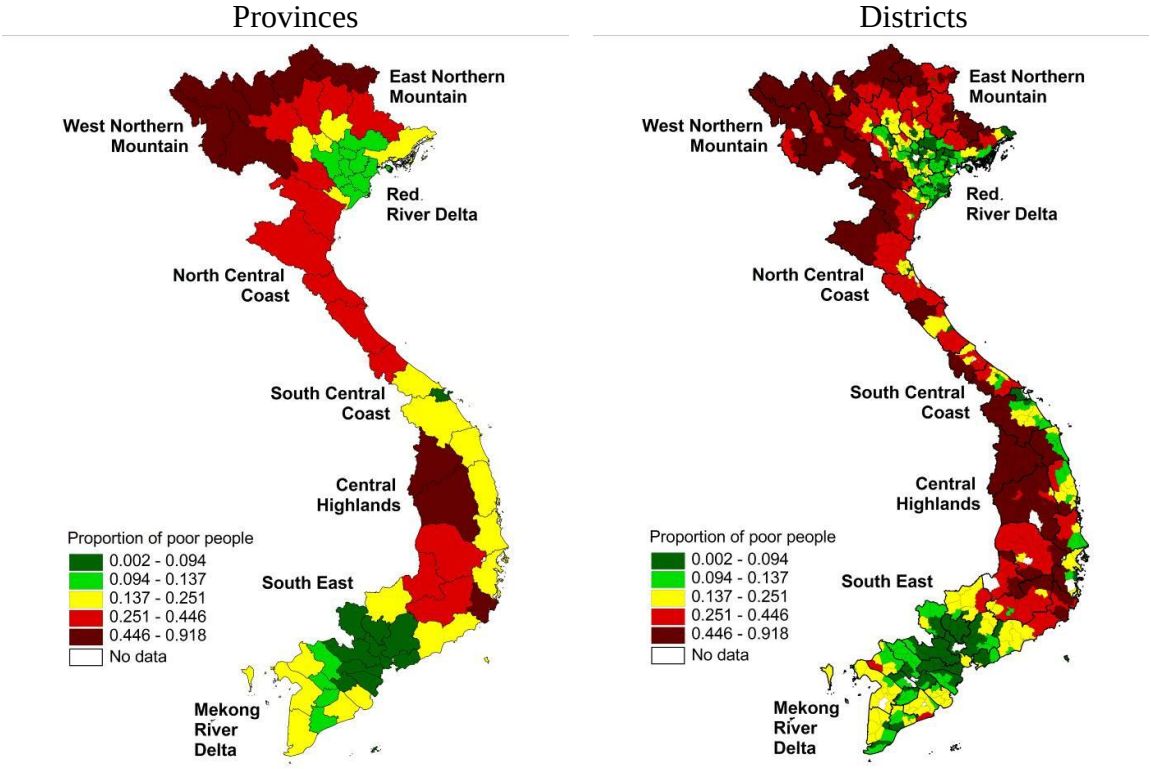
Regions	The effect on log of per capita expenditure			The effect on per capita expenditure		
	The effect of storms	The effect of floods	The effect of droughts	The effect of storms	The effect of floods	The effect of droughts
Red River Delta	-0.0421***	-0.0336***	-0.0353***	-187.6***	-144.4***	-163.5***
	(0.0081)	(0.0107)	(0.0119)	(40.8)	(54.6)	(57.6)
East Northern Mountain	-0.0619***	-0.0468***	-0.0472***	-207.8***	-161.7***	-180.3***
	(0.0105)	(0.0124)	(0.0141)	(38.0)	(46.4)	(49.8)
West Northern Mountain	-0.1170***	-0.0674***	-0.0327	-299.1***	-171.0***	-87.4
	(0.0204)	(0.0155)	(0.0270)	(53.1)	(41.2)	(70.1)
North Central Coast	-0.0481***	-0.0780***	-0.0597***	-162.0***	-277.1***	-213.2***
	(0.0088)	(0.0110)	(0.0169)	(31.6)	(40.1)	(60.3)
South Central Coast	-0.0449***	-0.0410***	-0.0363**	-185.1***	-164.0***	-158.6**
	(0.0087)	(0.0106)	(0.0146)	(35.5)	(44.7)	(59.1)
Central Highlands	-0.0765***	-0.0540***	-0.0287	-259.7***	-187.1***	-101.8
	(0.0219)	(0.0118)	(0.0261)	(78.6)	(44.0)	(93.4)
South East	-0.0202	-0.0169	-0.0075	-74.4	-48.0	-10.8
	(0.0187)	(0.0200)	(0.0210)	(117.9)	(137.1)	(128.7)
Mekong Delta	-0.0334**	-0.0325**	-0.0348**	-164.5**	-162.8**	-165.2**
	(0.0132)	(0.0144)	(0.0144)	(66.9)	(74.0)	(72.2)

Note: *** p<0.01, ** p<0.05, * p<0.1
Robust standard errors are in parentheses.
Source: Authors' estimation from the VHLSSs 2004, 2006, 2008 and 2010.

Figure 2 presents the poverty rate of provinces and districts of Vietnam in 2006. Figure 3 and 4 presents the impact of disasters on at the province and district levels, respectively. There are some noticeable findings from these figures. Firstly, there is a strong correlation between the poverty and the impact of disasters. Provinces and districts with high poverty rate tend to be more affected by disasters, or be less resilient to disasters.

Secondly, there is a large variation in the effect of disasters within regions and within provinces. Within a province, there are some districts with more and some district with less resilience to disasters. Thirdly, in some areas the effect of disasters differs for different types of disasters. Areas with different characteristics can have different resilience levels to different disaster types (storms, floods and droughts).

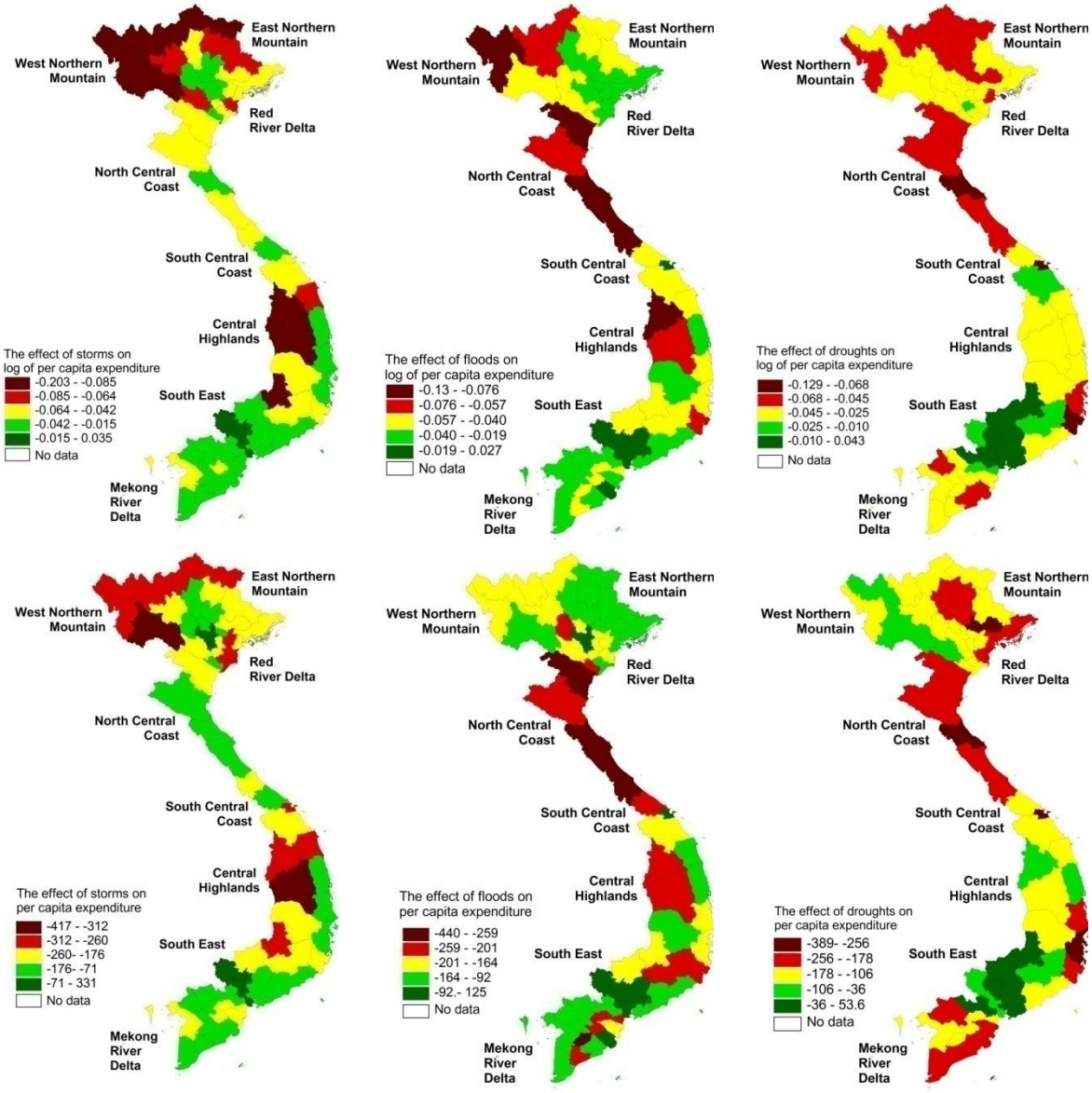
Figure 2: The proportion of poor population



Source: Authors' preparation using data on poverty from Nguyen et al. (2010)[11]

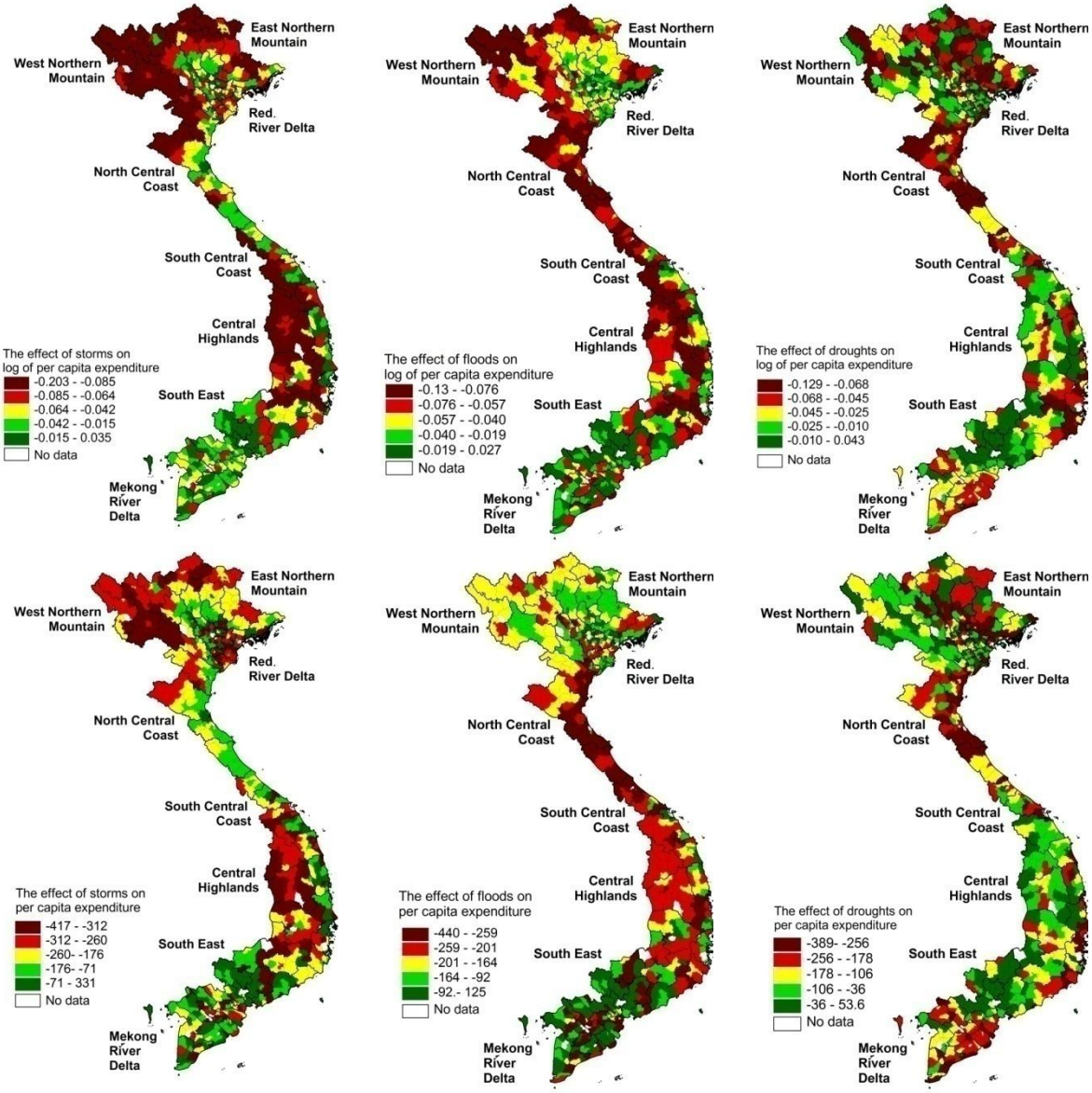
[11] We used ArcGIS software to make the maps in this study.

Figure 3: The effect of disasters at the provincial level



Source: Authors' preparation using estimates from VHLSSs

Figure 4: The effect of disasters at the district level



Source: Authors' preparation using estimates from VHLSSs

6. Conclusions

The paper estimates the effect of natural disasters on household welfare in Vietnam,and subsequently investigates different household and community characteristics that can strengthen resilience of households to natural disasters. It finds thatall the three disaster typesconsidered in this study including storms, floods and droughts have a negative effect on household income and expenditure. Per capita income of households living in a

commune with storms, floods and droughts decreases approximately by 1.9%, 5.9%, and 5.2%, respectively. Similarly, per capita expenditure is reduced by storms, floods and drought by around 1.5%, 4.4%, and 3.5%, respectively. Living in a commune with floods can increase the probability of being poor 0.018.

The effect of storms tends to be lower for Kinh households and households with smaller size and a higher proportion of working-age members. In other words, these households are more resilient to disasters than ethnic minority households and households with a large number of members, especially members not in working age. Households with high education are more resilient to floods and droughts than those with low education. Micro-credit, internal remittances and social allowances can help households mitigate the adverse effect of natural disasters.However, access to improved infrastructure is not strongly correlated with the resilience level of households. Households in communes with higher expenditure mean and more equal expenditure distribution are more resilient to natural disasters.

We find a great spatial variation in the resilience level to disasters. Poor provinces and district in West Northern Mountains and Central Highland have the lowest resilience to disasters, while rich provinces and districts in South East and Red River Delta have the highest resilience to disasters. Within a province, the resilience level differs for different disaster types and varies across districts.

The empirical findings can suggest several policy implications. Firstly, disasters cause harmful effects on households, and there is a largely heterogeneous effect of disasters. Disadvantageous households in poor areas with limited access to finance sources can be most affected by disasters, and they should receive supports from the government to cope with disasters. Secondly, programs targeted directly households such as credit and transfers might be more effective in mitigating the adverse effect of disasters than programs targeted at communes such as infrastructure improvements.

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Appendix

Table A.1. Summary statistics of variables

Variable	Type	Mean	Std. Dev.
Per capita expenditure (thousand VND)	Continuous	4602.9	3322.6
Per capita income (thousand VND)	Continuous	6468.7	11751.1
Poor household (poor=1, non-poor=0)	Continuous	0.1982	0.3986
Commune affected by storm during the past two years (yes=1, no=0)	Binary	0.1534	0.3603
Commune affected by flood during the past two years (yes=1, no=0)	Binary	0.1598	0.3664
Commune affected by drought during the past two years (yes=1, no=0)	Binary	0.1057	0.3075
Household size	Discrete	4.2364	1.7013
Proportion of adults from 15 to 60 in households	Continuous	0.6394	0.2740
Ethnic minorities (Ethnic minorities=1, Kinh/Hoa=0)	Binary	0.1913	0.3934
Age of household head	Discrete	48.722	14.024
Gender of household head (female=1, male=0)	Binary	0.2037	0.4027
Proportion of members with upper-secondary degree	Continuous	0.0758	0.1538
Proportion of member with college/university	Continuous	0.0675	0.1678
Crop land area (1000 m2)	Continuous	1.3247	2.6837
Per capita living area (m2)	Continuous	16.904	12.045
Commune with road passable all 12 months	Binary	0.7597	0.4273
Commune with irrigation system	Binary	0.6447	0.4786
Commune with a market	Binary	0.2729	0.4455
Commune with firms	Binary	0.6135	0.4870
Micro-finance from Vietnam Bank for Social Policies (million VND)	Continuous	0.6237	2.2884
International remittances (million VND)	Continuous	0.6648	5.9341
Internal remittances (million VND)	Continuous	1.6307	5.7274
Social allowances (million VND)	Continuous	0.3129	1.4367
Proportion of villages in commune with national electricity grid	Continuous	0.9442	0.1769
Number of market in communes	Discrete	0.9781	0.9221
Mean per capita expenditure of commune (million VND)	Continuous	4.4526	1.2799
Population of commune (thousand VND)	Continuous	8.1099	4.2972

Source: Authors' estimation from the VHLSSs 2004, 2006, 2008 and 2010.

Table A.2. OLS regressions of household outcomes

Explanatory variables	Log of per capita income		Log of per capita expenditure		Poverty status (Poor=1, Non-Poor=0)	
	Small model	Large model	Small model	Large model	Small model	Large model
Commune affected by storm	-0.0128	-0.0181*	-0.0194**	-0.0176**	0.0106*	0.0083
	(0.0100)	(0.0095)	(0.0081)	(0.0076)	(0.0060)	(0.0063)
Commune affected by flood	-0.1019***	-0.0879***	-0.0786***	-0.0670***	0.0238***	0.0238***
	(0.0099)	(0.0093)	(0.0080)	(0.0074)	(0.0059)	(0.0061)
Commune affected by drought	-0.0628***	-0.0545***	-0.0380***	-0.0336***	0.0145**	0.0128*
	(0.0119)	(0.0113)	(0.0096)	(0.0090)	(0.0072)	(0.0074)
Household size	-0.0632***	-0.0088***	-0.0708***	-0.0254***	0.0341***	0.0208***
	(0.0022)	(0.0025)	(0.0018)	(0.0020)	(0.0013)	(0.0016)
Proportion of adults from 15 to 60 in households	0.5615***	0.3868***	0.4812***	0.3106***	-0.2521***	-0.1911***
	(0.0131)	(0.0138)	(0.0106)	(0.0109)	(0.0079)	(0.0091)
Ethnic minorities	-0.5040***	-0.4380***	-0.4863***	-0.3995***	0.3595***	0.3168***
	(0.0094)	(0.0098)	(0.0076)	(0.0078)	(0.0056)	(0.0064)
Age of household head		-0.0015***		-0.0006***		0.0001
		(0.0003)		(0.0002)		(0.0002)
Gender of household head (female=1, male=0)		-0.0733***		-0.0541***		0.0440***
		(0.0092)		(0.0073)		(0.0061)
Proportion of members with upper-secondary degree		0.3387***		0.5415***		-0.2114***
		(0.0239)		(0.0189)		(0.0157)
Proportion of member with college/university		0.9563***		0.7602***		-0.2070***
		(0.0213)		(0.0169)		(0.0140)
Crop land area (1000 m2)		0.0433***		0.0219***		-0.0067***
		(0.0013)		(0.0010)		(0.0009)
Per capita living area (m2)		0.0142***		0.0127***		-0.0039***
		(0.0003)		(0.0003)		(0.0002)
Commune with road passable all 12 months		0.0341***		0.0503***		-0.0405***
		(0.0089)		(0.0070)		(0.0058)
Commune with irrigation system		-0.0313***		-0.0237***		0.0014
		(0.0075)		(0.0059)		(0.0049)
Commune with a market		0.0719***		0.0555***		-0.0269***
		(0.0080)		(0.0063)		(0.0052)
Commune with firms		0.0878***		0.0713***		-0.0410***
		(0.0075)		(0.0060)		(0.0049)
Year 2006	0.1649***	0.1534***	0.1303***	0.1138***	-0.0388***	-0.0290***
	(0.0101)	(0.0110)	(0.0082)	(0.0087)	(0.0061)	(0.0072)
Year 2008	0.2634***	0.2138***	0.2625***	0.2064***	-0.0491***	-0.0239***
	(0.0101)	(0.0110)	(0.0082)	(0.0087)	(0.0061)	(0.0072)
Year 2010	0.4122***	0.3155***	0.5211***	0.4390***	-0.0541***	-0.0290***
	(0.0103)	(0.0115)	(0.0083)	(0.0091)	(0.0062)	(0.0075)
Constant	8.3286***	7.8486***	8.1313***	7.6882***	0.1743***	0.3386***
	(0.0141)	(0.0254)	(0.0114)	(0.0201)	(0.0085)	(0.0167)
Observations	27,404	27,404	27,407	27,404	27,404	27,407
R-squared	0.246	0.390	0.350	0.478	0.208	0.238
Number of communes	4,629	4,629	4,629	4,629	4,629	4,629

Note: *** p<0.01, ** p<0.05, * p<0.1
Robust standard errors are in parentheses.
Source: Authors' estimation from the VHLSSs 2004, 2006, 2008 and 2010.